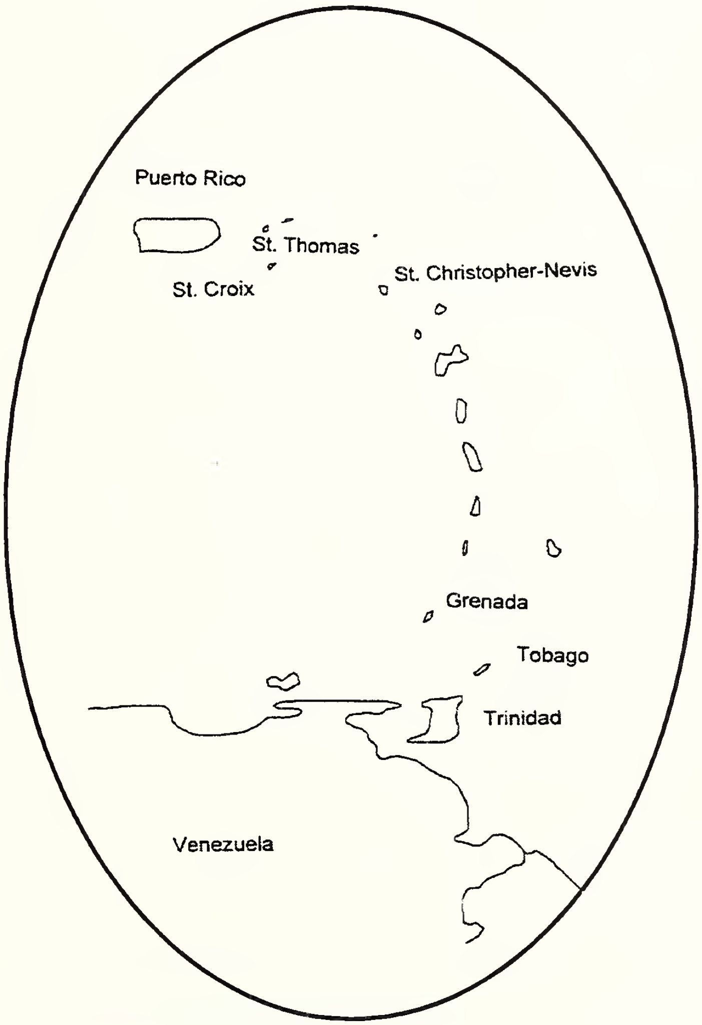
Pathway Risk Assessment

Pink Mealybug from the Caribbean



Planning and Risk Analysis Systems
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Executive Summary

A mealybug new to the Caribbean poses a risk for many plant species in the United States. *Maconellicoccus hirsutus*, commonly known as pink mealybug (PMB) or hibiscus mealybug, threatens tropical and subtropical ornamentals and tree fruits with some damage to warm weather vegetables, grape, and citrus. The mealybug would also have a negative impact on interstate and international movement of agricultural products. Establishment of PMB would endanger ecosystems in the U.S. Virgin Islands, Puerto Rico, and Florida.

To help determine what Animal and Plant Health Inspection Service (APHIS) needed to do, a risk assessment was conducted of the pathways for this mealybug from the Caribbean into the United States. The results indicated that this pest will become established in the southeastern United States in the near future. Infested host material from the Caribbean will enter primarily through such pathways as stores on yachts and sport fishing boats and as propagative material in air passenger and crew baggage. Pathways of more moderate risk were identified as aboveground consumption material carried in cargo and air passenger baggage, as propagative material in cargo, and in the stores, quarters, holds, garbage, and crew baggage of cargo ships. Increased risk management of the high and moderate risk pathways could postpone establishment in the United States.

But management of these pathways will not prevent establishment or spread of PMB when the source of heavy infestations continues to exist and expand its range to neighboring countries in the Caribbean. The lack of a known effective chemical control and an inability to eradicate this pest once it is established will aid in its spread. Effective management of this pest will probably come from the introduction of long-term biological control agents. APHIS involvement in the introduction of these agents could sharply reduce the explosive populations of this pest to tolerable population levels in the non-U.S. Caribbean, thereby reducing its rate of spread. Work on these agents, in particular, would also help us to develop a long-range, effective pest management tool before this pest becomes established in the United States.

Contents

Participants

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Introduction

Objective

This pest risk assessment has been prepared in response to the severe infestations of a mealybug species—pink mealybug (PMB)—recently discovered in the Caribbean. This mealybug has an extremely wide host range, is difficult to detect and control, and can multiply and spread rapidly. Severe infestations have cost Grenada millions in agricultural, environmental, trade, and social costs; severe losses there suggest it could be damaging here also. Its rapid spread to Trinidad and St. Kitts suggests that it could spread to surrounding countries. To avoid similar losses, neighboring countries are working together to keep this pest out of their countries, to reduce the mealybug levels in the infested area, and yet continue agricultural trade. Because of this situation, Jorge and Castleton (1996) assessed the risk of cargo movement from the infested area among Caribbean and South American countries. While for the United States, Plant Protection and Quarantine (PPQ) in the southeastern region requested that we conduct a risk assessment of PMB pathways, including natural spread, into the United States. The issue was, What can we do to prevent its entry into the United States? To answer that question, we needed to determine the level of risk presented by the various pathways that PMB can use to enter the United States, particularly through the southeastern PPQ ports that are the gateways from the infested islands. We could then recommend options on safeguards needed to ensure that commodities moving from the Caribbean to the United States pose no significant risk from PMB.

Methodology–Expert Group

Several steps were used to attain this objective. First, an expert group was put together for assessing the evidence. The participants are listed on page 1. These federal and State representatives contributed expertise in mealybug identification and biology, in regulatory activities both air and maritime, and in biocontrol. Then, the analysts compiled and submitted the evidence to the expert group for review. The experts were asked to provide additional evidence that they believed relevant.

The expert panel then met at Ft. Lauderdale, Florida, from April 30 through May 1, 1996. They were introduced to the risk analysis process and given the highlights of the generic pest risk assessment process. The generic process was developed by Orr et al. (1993).

Generic Process

We used the generic risk assessment process to assess the pathways in qualitative terms, based on the evidence (See evidence, E1–E11, in appendix 2) and on knowledge. The analysts elicited knowledge from the experts through the approach developed by Kaplan (1992). The experts were not asked their opinion of the risk, but what facts they knew about the various parameters. The participants reviewed, presented, discussed, and if possible, agreed on the meaning of the information and their knowledge relevant to the parameter. Consensus was sought whenever possible.

The participants identified the hazards, listing all possible pathways that could carry PMB. Following the process by Orr et al. (1992), the group then assessed the relative level of risk for these pathways, using the establishment and consequence models described below. The participants determined qualitative estimates for each parameter and their level of uncertainty about the knowledge and data.

The probability of establishment by an organism is described as

$$P_1 \; P_2 \; P_3 \; P_4 = P_E$$

where
P_1 = probability of the organism moving with the host/commodity or hitchhiking in containers and vehicles
P_2 = probability of surviving transit, escaping detection, and entering the United States
P_3 = probability of overcoming environmental resistance to find a host and to colonize and maintain a population
P_4 = probability of spreading beyond the colonized area to reproduce, colonize, and spread
P_E = probability of becoming established.

The consequence of establishment is described as

$$I_1 \; I_2 \; I_3 = C_E$$

where
I_1 = potential impact of economic damage
I_2 = potential impact of non–\$\$ environmental damage
I_3 = potential impact of perceived damage (social and political influences)
C_E = consequence of establishment

Note: The parameters are *not* multiplied. To determine the probability and consequence of establishment, see appendix 1.

The results were summarized and served as the basis for the management options recommended by the panel.

We did not determine the pest risk potential (PRP) because it was not necessary to our objective, which was to determine the risk potential of the pathways for the pest, not the risk potential of the pest. The information, however, is present so that anyone who chooses, may do the PRP estimates.

Definitions

Hazard—potentially harmful element or event, an adverse event or outcome

Hazard identification—describes what might go wrong and how this might happen

Risk—likelihood (probability) and magnitude (the consequences) of an adverse event occurring, a measure of the probability of harm and severity of the adverse effects

Risk analysis—the process that includes risk assessment, risk management, and risk communication

Risk assessment—a process of identifying hazards, estimating the probability for each adverse event to occur, and estimating the magnitude of the consequences

Risk management—process of identifying, evaluating, and recommending alternatives for mitigating risk

Risk communication—open exchange of information and opinion leading to a better understanding of risk and risk-related decisions

Acknowledgments

The authors sincerely thank all the members of the expert group for their work in making this risk assessment effective. Others who have contributed include Jeffrey Bruff, Joe Cavey, Michael S. Hornyak, and Michael J. Shannon. Special thanks are extended to Pedro Jorge and Doug Odermatt for supplying extensive, critical information.

Pathway Assessment

State the Question

Determine the level of risk presented by each pathway for *Maconellicoccus hirsutus* from the Caribbean into the United States. Particular attention was to be paid to PPQ ports in the southeastern region: the U.S. Virgin Islands, Puerto Rico, and Florida because these locations are the first U.S. ports of entry from the Caribbean.

Summary of the Pest—

Nomenclature

Belonging to the family Pseudococcidae, *Maconellicoccus hirsutus* (Green) has been previously reported as *Pseudococcus hibisci* Hall or *Phenacoccus hirsutus* Green. It is commonly known as pink mealybug because of its color. We will refer to it as PMB. The literature also refers to it as "hibiscus mealybug" or "grape mealybug" because of its damage to these hosts.

Distribution

Mani (1989) described the distribution as in the Oriental, Australian, Palearctic and Ethiopian regions. Besides the countries listed in these areas by the CAB International Institute of Entomology (1987), Pakistan (Ghani and Muzaffar 1974) and other Pacific islands (Williams and Watson 1988) have been reported infested, as well as Hawaii (Beardsley 1985, the State of Hawaii Department of Agriculture 1994) and Guam (Beardsley 1986).

PMB was first identified in the Caribbean in Grenada in November 1994, although it may have been present 18–25 months earlier. Infestations are currently widespread in Grenada and Carriacou (Francis-Ellis 1995). By late May 1995, it was identified in Trinidad, where it remains in urban areas (Programme Management Committee 1995). By October 1995, it was confirmed for St. Christopher (also known as St. Kitts). As of late February 1996, infestations in St. Kitts were still restricted to residential areas, involving over 400 residences; one-fourth of these residences were up to 5 km outside the main infested area (Thomas and Thomas 1996).

Hosts

PMB is an extremely polyphagous species. (Appendix 2, E9, lists many of these hosts, but this list does not include all hosts in the literature.) Based on E9, PMB affects at least 74 families worldwide with 67 in the Caribbean, about one-half more than reported in the Old World. It affects a total of almost 200 genera with about 144 in the Caribbean or about two-fifths more than reported in the Old World. Some major crop families include mango, legume, grass, hibiscus, fig, palm, coffee, citrus, and grape. Hall (1922, 1923) reports the most heavily infested genera in Fabaceae, Malvaceae, Moraceae, Proteaceae, and Rhamnaceae.

In Grenada, PMB affects over 90 crop and forest species, including vegetables, tree fruits, forest trees, ornamentals, and weeds (Francis-Ellis 1995, Persad 1995, Programme Management Committee 1995). In Trinidad over 130 species are affected. Crops at risk are sugarcane, teak, vegetables, ornamentals, orchard crops, cocoa, and a germplasm bank (Programme Management Committee 1995). PMB has been identified in St. Kitts on over 40 species. Sugar and domestic food crops are particularly threatened (Programme Management Committee 1995, Thomas and Thomas 1996).

Biology

The life cycle generally takes about a month, although it can drop to 23 days under laboratory conditions (Ghose 1972a). Theoretically, there could be 15 generations, but this number is doubtful under natural conditions. Ten generations in India (Fletcher 1919) is the maximum number reported in the literature examined. Cooler weather or lack of hosts would extend the life cycle well beyond a month even in India (D. Odermatt, pers. comm.).

Mani (1989) reviewed the studies of many workers who studied the life cycle. PMB overwinters in the egg stage in the Mediterranean climate of Egypt (Hall 1921), but as fully grown females in India (Ghose 1972a). Females continued to survive 12 °C (53.6 °F), the lowest temperatures reported for this species (Babu and Azam 1987) in the literature examined. Overwintering occurs in the shelter of bark crevices, leaf scars, under bark, in stem notches, in the soil (Misra 1920b, Singh and Ghosh 1970), tree trunks, between the ingrowing callus and cut surface where a branch has been cut off (Hall 1921), inside bunches of fruit clusters, and inside or between crumpled leaf clusters (Beshir and Hosny 1939, Mani 1989).

The female lays eggs in a terminal ovisac, which is loose, cottony, and white. She deposits from 84 to over 600 eggs, the number depending on the host species. Freshly laid eggs are orange, becoming pink before hatch (Ghose 1972a). The female shrinks as the eggs are laid, and she dies after egg laying, in about a week (Hall 1921).

After hatching, the active crawlers seek tender growth to feed. They favor the young stem just behind the growing point, petiole, or under surface of leaves, particularly the junction of petiole and leaf. They often move to new sites, settling in colonies (Hall 1921, Singh and Ghosh 1970). Older plant parts, such as the stems, leaves, petioles, and pods, could also be heavily infested. Hall (1921) noted that PMB tends to seek a sheltered position out of view. Nymphs undergo three instars in the females and four in the males (Ghose 1972a). Females are wingless and dark pink; males are winged. Hall (1921)

presumed parthenogenetic reproduction; no scientific studies have been reported in the literature to support this mode of reproduction for PMB. Work by Ghose (1972a) demonstrated only sexual reproduction: isolated females laid no eggs. During late autumn and winter, the female seeks a sheltered position to lay her eggs, usually ending in a gathering of similar females. In the summer, females may not seek shelter to lay eggs (Hall 1921).

Symptoms first appear on the growing points. Shoots become twisted with shortened internodes, forming bunchy heads of small bushy leaves at the tips (Hall 1921, 1926), assuming a multiheaded appearance with multiple damage (Pushpa Veni et al. 1973). In heavy infestations, leaves and shoots become compact and crisp. Plants of mesta (also know as kenaf—a fiber and oil crop) look like sticks with a cluster or bunch of small, crispy leaves on top; mulberry shows only bare stems (Misra 1920b, Singh and Ghosh 1970, Francis-Ellis 1995).

Symptoms on mulberry are known as Tukra disease (Misra 1920b). On mango, infested flowers dry and drop, resulting in fewer, smaller, abnormally shaped fruit that may drop early. Severely defoliated saman trees die (Frances-Ellis 1995). Mesta later dies (Misra 1920b, Singh and Ghosh 1970).

PMB is one of the few mealybug species reported to have a toxic saliva, which stunts and kills young shoots. Curled leaves resemble viral damage. De Lotto (1967) suspected PMB as a viral vector from observing symptoms. A study showed that infested plants revived after PMB was removed when symptoms appeared, but growth remained less than in uninfested plants (Singh and Ghosh 1970).

Population Dynamics

Several factors favor PMB infestations: weather, host preferences, perennial versus annual host growth, weak or young growth, and apical portions of plants.

The rate of development shortened with increasing temperatures, but lengthened with rising relative humidity (Babu and Azam 1987; Mani and Thontadarya 1988, cited by Mani 1989). Populations built up rapidly during dry spells of more than 2 weeks in India (Pushpa Veni et al. 1973) and after intensely hot, dry weather in Trinidad (Jones 1996b); they dropped with the onset of monsoons in India (Pushpa Veni et al. 1973). This mealybug apparently can withstand desert temperatures and humidity, for it has infested crops in Saudia Arabia. There, it survives on irrigated crops in the shady parts of plants, such as in the middle of fruit bunches (Talhouk 1993).

Although PMB affects hundreds of plant species, the number able to support PMB through its entire life cycle is much less (See E9). Also, the amount of damage exhibited by a plant species may be unrelated to the reproductive ability of PMB on that host. Some heavily damaged plant species carry very small to nonexistent colonies of PMB; other species showing mild symptoms may carry heavy colonies. Population size may indicate reproductive potential (Hall 1921, Ghose 1972b). Several authors refer to the heavily colonized hosts as primary hosts.

Hall (1921) noted that annual crops in Egypt are generally not seriously infested unless they are near heavy infestations. Primary food plants were among the permanent shrubs and trees. By helping PMB to overwinter, these perennial plants became the infestation reservoir for new plants.

The degree of attack depends on the health of the plant and its species susceptibility to attack (Hall 1921). Healthy trees resist infestations for several years before succumbing. Seedling trees and weakened trees are more susceptible. Heavy infestations on citrus and mango may stunt seedling growth, but have little effect on bearing-age trees that are not near heavy infestations (Hall 1926).

Although PMB seems to infest any plant part, Ferguson (1995) noted that PMB prefers to colonize fruit and flower parts over other plant parts. Also, a few workers noted PMB on underground parts. Hall (1921) reported it on potato tubers and once on *Daradixa* roots. Hosny (1939) reported one case each on roots of beans and on underground parts of peanuts growing under heavily infested trees. Siva Rao and Srinivasan (1987) described it feeding only on underground parts (roots, pods, and pegs) of peanuts for two seasons in India after the rainy season.

PMB spread is mainly due to dispersal of the 1st instar (Ghose 1972a). Misra (1920b) reported that newly hatched nymphs can walk long distances to their favorite food plants. Nymphs and fully grown females have crawled out of a ditch or pool of water where infested prunings were discarded, and reentered the field.

Factors that contribute to its spread include: hot, windy weather; improper disposal of infested material; distribution of infested plants from commercial nurseries; transport and distribution of infested produce by vendors; home boxes and concealed cargo; transport of PMB on clothing and/or bodies of handlers and animals; association with mobile insects; surface runoff (Jones 1995); and spread by vehicles, tools, and instruments (Francis-Ellis 1995).

Hazard Identification

Before the experts met, table 1 containing hazard activities 1 through 21 was submitted to the group to examine. During the meeting, brainstorming added hazards 22 through 24. Similar activities were then grouped together. Each hazard on the new list was examined as to whether it could be a pathway, how often it occurred, and whether it should be analyzed for risk.

The expert group eliminated hazard 2 as a pathway because Guam and Hawaii are outside the scope of this assessment, and Puerto Rico and the U.S. Virgin Islands are not infested. Hazards 4 and 7 were eliminated for the same reason.

The group also eliminated the following hazards as non-PMB pathways: hazard 11, naval ships; 15, commercial aircraft stores; 16b, travelers from Canada in cars; 18a and 18b, travelers from Mexico by air or car; 19, commercial shipments of live animals; and 24, garbage dumped from ships.

During assessment of the pathways, the expert group determined that hazard 3, stores, quarters, holds, and garbage of aircraft had different risk levels for commercial and private aircraft, so these two were split. J. Bruff (PPQ pers. comm.) noted that cargo planes regularly flew into Miami from the Caribbean. Cargo planes were combined with passenger aircraft because of similarities in risk. Commercial aircraft was later dropped because these would probably carry non-Caribbean produce while private planes would be more likely to carry local fruits and cut flowers.

Thus, hazard identification targeted 12 pathways to be considered for risk assessment, as listed in table 1, column 4.

Table 1. Hazard Identification*

Possible hazards	Potential pathway for PMB: Yes, Maybe, No	Frequency: Common, Some, Rare, None	Consider for risk analysis: Yes, Maybe, No
1. Air passenger and crew baggage from foreign areas	Y	C	Y
2. Air passenger and crew baggage from outlying U.S. areas: Guam, Hawaii, Puerto Rico, U.S. Virgin Is.	n.a.	—	N

* See explanation of codes at end of table.

Table 1. Hazard Identification*—Continued

Possible hazards		Potential pathway for PMB: Yes, Maybe, No	Frequency: Common, Some, Rare, None	Consider for risk analysis: Yes, Maybe, No
3. Aircraft (stores, quarters, holds, garbage)	3a. Commercial (passenger & cargo planes)	N	—	N
	3b. Private	Y	S	M
4. Domestic mail from Hawaii		n.a.	—	N
5. Foreign mail		Y	S	M
6. Express mail carriers from foreign areas		Y	C-	Y-
7. Express mail carriers from Hawaii		n.a.	—	N
8. Cargo ships (stores, quarters, holds, garbage, crew baggage)		Y	C	Y
9. Cruise ships (stores, quarters, garbage, baggage)		Y but seldom for stores	S	M
10. Yachts and sport fishing boats (stores, quarters, garbage, baggage)		Y	C	Y
11. Naval ships (stores, quarters, garbage, crew)		N	—	N
12. Commercial fishing ships (stores, quarters, garbage, crew)		M	R	N
13. Cargo, Permit: direct from infested area, including hitchhikers, those not associated with host material		Y	C	Y
Pathways through Canada				
- 14. Cargo		M	R	Mn
- 15. Aircraft stores		N	—	N
- 16. Traveler's baggage by	16a. Air	Y	N	N
	16b. Car	N	—	N
Pathways through Mexico				
- 17. Cargo from Third Countries		Mn	R	N
- 18. Traveler's baggage by	18a. Air	N	—	N
	18b. Car	N	—	N
19. Commercial shipments of live animals		N	—	N

Table 1. Hazard Identification*—Continued

Possible hazards	Potential pathway for PMB: Yes, Maybe, No	Frequency: Common, Some, Rare, None	Consider for risk analysis: Yes, Maybe, No
20. Pest not associated with host material	Included in 13. Cargo	—	—
21. Natural spread	Y	R to C	Y
22. Air passengers and baggage moving materials from an infested area to a noninfested area, then to U.S. ports	Y	C	Y
23. Cargo moves from northern to southern United States	M	Uncertain	Y
24. Garbage dumped from ships floats to land and becomes source of infestation	N	—	N

* Abbreviated options use the first letter of each option, e.g. "Y" for Yes. A '-' indicates a degree lower than the stated option, e.g. "C-" for somewhat less than *Common* but more than *Some*. Where the expert group disagreed, a capital/lowercase letter indicates the majority/minority view, respectively.

Probability of Establishment

The expert group then examined the above 12 pathways for probability of establishment. The experts first assessed all "Yes" pathway items from the last column and then the "Maybe" items. The pathways include in the order assessed (Their reference numbers from table 1 are in parentheses.):

- Permit cargo moved directly from infested area (13), including hitchhikers (20)
- Air passenger and crew baggage from foreign areas (1)
- Cargo via Canada or northern United States to southern United States (14, 28)
- Air passengers and baggage moving materials from an infested area to a noninfested area, then to U.S. ports (22)
- Express mail carriers from foreign sources (6), and foreign mail (5)

- Stores, quarters, holds and crew baggage as applicable, and garbage on cruise ships (9), yachts and sport fishing boats (10), aircraft (3b), cargo ships (8)

- Natural spread (21)

The analyst divided the commodities into groups each pathway would carry. Probabilities of establishment may vary for the commodity divisions, depending on the use of the material (propagative versus consumption); the size and physical surface of the material (single, large fruits may be easier to inspect than others that have more nooks and crevices for PMB to hide, such as fruit clusters, leafy vegetables, herbs); whether the plant part is removed from above or below ground (Below ground material is less likely to be infested but more likely to be propagable); and cut flowers (While considered consumption material, cut flowers may be more likely than fruits and vegetables to be discarded. Infested discards in the environment may lead to PMB infesting adjacent hosts.).

The expert group discussed each pathway and its commodity groups and reviewed the evidence (See evidence E1–E11 in appendix 2) and the participants' knowledge. Based on this discussion, the experts assigned the probability for each event to occur and the certainty they felt about the validity of the evidence. Table 2 summarizes these estimates, followed by a discussion of how the estimates were derived. The last five pathways do not list commodity groups because the assessment results showed no differences among them.

Permit Cargo

This permit cargo arrives directly into southeastern regional ports from infested Caribbean sources.

Pest on commodity (P_1): Tropical foliage plants and orchids arriving as propagative materials from the infested Caribbean islands (E4, E5, and E6) in limited amounts may or may not be known hosts (E9) of the PMB, so a moderate rating is given with a reasonably uncertain (RU) rating. The known biology of PMB indicates that it would be associated with aboveground plant parts including fruit, green stems, and leaves (G).

Most of the cut flower shipments are listed as hosts (e.g., *Anthurium*, *Rosa*, and *Alpinia* (E4, E5, E6, and E9)), but cut flower shipments are generally not found infested with mealybugs (E1 and G). Because most of the cut flowers are identified to genus, an MC code is given for uncertainty.

Table 2. **Pathway Risks***

Pathways	P1: pest on commodity	P2: survives transit, enters with normal inspection	P3: pest colonizes	P4: pest spreads	Probability of establishment
Cargo, Permit					
• Propagative	M (RU)	H (RC)	H (VC)	H (VC)	M (RC)
• Fruit: single and large fruit	H (RC)	H (RC)	M (RC)	H (VC)	M (RC)
• Other fruits & vegetables: berries, leafy vegetables, fresh herbs	H (MC)	H (VC)	M (RC)	H (VC)	M (RC)
• Underground plant parts	L (RC)	H (RC)	M (RC)	H (VC)	L (RC)
• Cut flowers	M (MC)	H (RC)	M (RC)	H (VC)	M (RC)
Air passenger and crew baggage from foreign areas					
• Propagative	H (VC)	H (VC)	H (VC)	H (VC)	H (VC)
• Fruits, leafy vegetables, fresh herbs, cut flowers	H (RC)	H (RC)	M (RC)	H (VC)	M (RC)
• Underground plant parts	L (RC)	H (RC)	M (RC)	H (VC)	L (RC)
Cruise ships (stores, quarters, garbage, baggage)	L (MC)	H (VC)	M (MC)	H (VC)	L (RC)
Yachts and sport fishing boats (stores, quarters, garbage, baggage)	H (RC)	H (VC)	H (MC)	H (VC)	H (RC)
Private aircraft (stores, quarters, holds, garbage)	H (RC)	M (RU)	L (RU)	H (VC)	L (MC)
Cargo ships (stores, quarters, holds, garbage, crew baggage)	H (RC)	M (RC)	H (RC)	H (VC)	M (MC)
Natural spread	L (RU)	L (RC)	M (RU)	H (VC)	L (RU)

* See appendix 1 for explanations of the codes and of the determination of the final probability of establishment.

Large fruit shipped from the infested islands are almost all known hosts. Many of these hosts have been found commonly infested with PMB from the Old World in passenger baggage shipments (E1, E4, E5, E6, and E9). One interception of Pseudococcidae (nymph) in Trinidad from Grenadian bananas and several recent interceptions from large fruits from Grenada (E3) also support a high rating for this element with reasonable certainty.

With less evidence available for the small fruit and vegetable group (E1-E9), the expert group still rated this group of host material as high but increased the uncertainty.

Although PMB has been reported to occur on underground plant parts (Hall 1921, Hosny 1939, and Siva Rao and Srinivasam 1987), interception records (E1) do not support this as a good pathway. Root crops exported from the infested areas in the Caribbean grow within the ground without tops exposed.

Entry potential (P_2): The expert group rated all types of permit cargo as high for this element based on the difficulty of detecting eggs, crawlers, or 2d instar nymphs (G) and the pest surviving air shipments on its host without a problem (G) (Pedgley 1982). We are more certain of this risk level for the small fruit and vegetable group than for the other groups because the size and/or growth habit of these hosts makes inspections more difficult.

Pest colonizes (P_3): Propagative material is rated high because PMB arrives on a live plant, and other hosts are likely to be available in the yards and other environments where the propagative material is destined. The type of plants imported from the Caribbean is likely to be used outdoors and in semi-enclosed outdoor areas in Florida, Puerto Rico, or the U.S.Virgin Islands (G).

Cut flowers, which may last about 2 weeks and can come into contact with live host material (e.g., in graveyards, backyards, parks, florist shops), received a moderate rating.

For the other material (large fruit, other fruit, vegetables, and underground plant parts), the expert group gave a moderate rating with reasonable certainty based on most of the cargo (E4-E6) requiring no refrigeration at home, moving in relatively large shipments, and on most of these food items being consumed or prepared near host plants (G).

Pest spreads—for this and all other pathways (P_4): Based on the history of this pest in Egypt (Hall 1926), Grenada (Francis-Ellis 1995), and Trinidad (Jones 1996), and based on the history of other mealybugs (e.g., Comstock

mealybug, *Pseudococcus comstocki* (Kuwana), in California and cassava mealybug, *Phenacoccus manihoti* Mat.-Ferr., in Africa), PMB is rated high for pest spread for all pathways. The host range (E9) is so wide that hosts will be available anywhere in the southeastern region where this pest can overwinter. The group was very certain with this element.

Air Passenger and Crew Baggage from Foreign Areas

Pest on commodity (P_1): Underground plant parts were rated as low based on the same evidence for the first pathway (cargo). The other groups of host material (aboveground plant parts plus cut flowers) were given a high rating for this element because the material is likely to be from the backyard or of non-export quality, thus more likely to be infested than cargo (G and E1).

Entry potential (P_2): The expert group rated all categories of host material moving in passenger baggage as high for this element based on the evidence given under the cargo pathway and based also on the large proportion of material smuggled in passenger baggage, escaping inspection (G).

Pest colonizes (P_3): Same as for Cargo

Results (P_E): Note that propagative material is rated as high and with VC certainty code.

Cargo Via Canada or Transshipped from Northern United States

The State of Florida found no cargo from the infested islands trucked into Florida via Canada or northern U.S. ports during their border inspection for the 6 weeks before this assessment began (Richard Clark). PPQ cargo supervisors at JFK found no evidence that cargo from the infested islands is moving south. Because this material is allowed entry, the importer would have no reason to hide this information. Data from the current Canadian border vehicle and cargo surveys (mainly during November and December 1995) gave no indication of host material moving south either as cargo or as traveler's lots. An inspection of Canadian-origin passenger baggage arriving at Orlando, FL, between November 9, 1995, to January 26, 1996 (17,853 passengers), revealed little evidence that air passengers are moving fruits from the infested islands via Canada (Vanechanos 1996).

Because no evidence for movement from the north was found, this pathway was not assessed. If cargo were moved, the risk would be similar to cargo arriving directly from the Caribbean.

Air Passenger Material Via a Noninfested Island

After much discussion, the expert group estimated that the risk here would be the same as for air passengers arriving directly from an infested island. PPQ officers at each of the ports of entry in Florida, Puerto Rico, and U.S. Virgin Islands need to determine at their ports which flights will arrive with these in-transit passengers.

Express Carriers

The group found no evidence and decided not to assess this pathway further until after the completion of the informational survey of express carriers currently being conducted at Miami. If material moves this way, the risk would be similar to passenger baggage lots.

Foreign Mail (Miami only)

Puerto Rico and the U.S. Virgin Islands do not have a foreign mail distribution center; Miami does. The group found little evidence of this hazard being a pathway, but this pathway warrants an information survey because of interceptions of host material in the mid–1980's. If material moves this way, the risk would be similar to passenger baggage lots.

Cruise Ships

Pest on commodity (P_1): Cruise ship stores are seldom loaded in the Lesser Antilles. The fruit on these ships is commonly of U.S. origin and of a high export quality. Few pests are ever intercepted from these stores. Garbage is properly safeguarded on this type of craft and would be mostly of non-Caribbean origin. Passenger baggage is the large risk, but most fruit taken ashore originates from the ship's stores, thus a low rating is warranted (G). The small amount obtained locally from the infested islands would have been eaten or discarded long before arriving in U.S. ports.

Entry potential (P_2): Basically no baggage is inspected, so the rating is high (G).

Pest colonizes (P_3): Because a large portion of the passengers leave for northern destinations after landing in Puerto Rico, U.S. Virgin Islands, and Florida, this element receives a moderate rating (G).

Results (P_E): A low P_1 results in a low probability of establishment.

Yachts (including sport fishing vessels)

Pest on commodity (P_1): Stores on yachts that visit infested islands are likely to include fruits and vegetables obtained from local markets. This produce is generally not of export quality and is likely to be infested (as observed by

several members of the expert group in the markets of the infested islands), so a high rating for this element is warranted with reasonable certainty.

Entry potential (P_2): Because PPQ generally does not board yachts in Florida and clears them in Puerto Rico only during regular working hours (8:00 a.m. to 4:30 p.m.), this rating is high.

Pest colonizes (P_3): Based on the lot sizes and potential infestation level of material that can be carried from the yachts, P_3 is rated as high.

Results (P_E): Although the frequency of yachts moving from the infested islands to U.S. locations may be small compared to that of air passengers, the probability of establishment of PMB via this pathway is high.

Private Aircraft
(stores and/or baggage)

Pest on commodity (P_1): Same as for yachts but may have cut flower arrangements along with fruit.

Entry potential (P_2): PPQ clears private planes only during regular working hours at most locations in the high risk area (Florida, U.S. Virgin Islands, Puerto Rico), so entry potential is moderate (G).

Pest colonizes (P_3): The expert group rated this as low with a reasonable amount of uncertainty, assuming a large portion of host plants would be unavailable on airport grounds.

Results (P_E): This is low because the pest colonization potential is low for this pathway.

Cargo Ships

Generally these ships are small cargo ships docking at the Miami river or from the English-speaking Lesser Antilles arriving at Puerto Rico or the U.S.Virgin Islamds.

Pest on commodity (P_1): Same as for yachts.

Entry potential (P_2): PPQ boards all of these ships on arrival, but as fruit can be easily hidden on these vessels, a moderate rating is given (G).

Pest colonizes (P_3): Same as for yachts.

Results (P_E): Based on a moderate rating for entry potential, the probability of establishment from cargo ships is also moderate.

Natural Spread
(between islands or from the islands to the U.S. mainland)

Pest on commodity (P_1): Three methods of natural dispersal were discussed: windborne (including pests attached to leaves); hitchhiking on birds, bats or even flying insects; and on drifting debris. The Caribbean and Antilles currents both move from east to west in a slightly northern direction and could move drifting plant material such as mangrove rafts and coconuts from an infested island toward U.S. locations. Animals adrift at sea on plant material is considered a common method of dispersal in the prehistoric Caribbean, but the expert group believed survival of mealybugs dispersed this way would be too low to present a significant risk for establishment.

In the laboratory, birds accumulated crawlers and ovisacs while foraging on host material infested with *Pulvinaria mesembryanthemi* (Vall.), a scale insect in California (Washburn and Frankie 1981). Also, *Adelges* are known to be dispersed by land birds in the northeastern United States. Once a year a large number of migratory land birds fly from South America through the Caribbean to the eastern United States. They could aid in dispersing PMB. Misra (1920b) observed transport of PMB eggs and nymphs to new places by nymphs and adults of *Pseudococcus virgatus* and other insects. Avas Hamon has observed Kermesidae crawlers hitchhiking on larger flying insects.

Wind can disperse pieces of the cottony ovisac with eggs and nymphs, or infested leaves and fruits long distances, especially from tall trees (Misra 1920, Hall 1921, Francis-Ellis 1995).

Pedgley (1982) reviewed several studies that used sticky board traps to demonstrate that air currents can disperse first instar nymphs (crawlers) of scales for 5 km (3.1 mi) (E10).

Greathead (1972) suggested that wind dispersal caused outbreaks of the armored scale *Aulacaspis tegalensis* (Zhnt.) 150 km (93 mi) and 260 km (162 mi) inland from the coastal infestation in Kenya. He supported this suggestion with some experimentation on wind speed, trap catches, crawler behavior, and terminal velocity but only for short distances.

Distances between the Caribbean islands range from relatively short distances such as the 4 km (2.5 mi) between St. Kitts and Nevis to the relatively long distances such as the 177 km (110 mi) between St. Kitts and St. Croix (E11).

Darlington (1938) made the following observations concerning overwater dispersal of terrestrial animals (either by air or sea movement) that pertain to the possible movement of PMB.

- The larger the population, the greater the chance of dispersal across a water gap

- An organism is more likely to populate large fertile islands than small, barren ones.

- Organisms are more likely to cross narrow gaps than to cross wide ones. What this means to us is that natural dispersal over water should result in an orderly distribution from the original infested island to the nearest island, without skipping islands. This statement can be expressed as a mathematical approximation:

$$X_b = X_a^{m/n}$$

  where
  X_a is the chance of an individual to cross a gap of
  m distance from the original infested site *0* to site *A*, and
  n is the distance between site *0* and site *B*, then
  X_b will be the chance of an individual to cross the second gap *n*.

  For example, two similar islands are at different distances from the source of infestation. The chance for a crawler to arrive at island "*A*" is 1 in 1,000 from the infested island, which is 3 km (2 mi) away. Island "*B*" is 6 km (4 mi), twice the distance of *A*, from the original infested island. Then the chance for the crawler to arrive at *B* would be 1/1,000,000 or 1,000 times less than for it to arrive at *A*. We have $X_a = 1/1000$, $m = 4$, $n = 2$, then $X_b = (1/1000)^{4/2} = (1/1000)^2$ $= 1/1000,000$.

The risk model used here for the other pathways does not quite fit natural dispersal. For example, pest movement (P_1) is associated with air currents or birds. The rating is estimated as low with reasonable uncertainty.

Entry potential (P_2): This includes survival potential to port of entry and is rated low for this pathway, although Pedgley (1982) does suggest that crawlers can survive windborne movement for 100 km (62 miles) or more. He states that coldness and dryness would negatively affect crawler survival.

Pest colonizes (P_3): After a long discussion about the possibility of parthenogenetic reproduction (see biology), which would greatly aid colonization for natural spread, the group rated this element as moderate. After long distance dispersal by wind or birds, only one or a few surviving crawlers would be found on the same host plant or even in the same general area.

Results (P_E): The expert group believes that over time natural dispersal between islands and the same island groups would occur, such as from Grenada, through the Grenadines to St. Vincent. With large PMB populations such as in Grenada, natural dispersal between island groups is possible, but movement by man would be likely to occur first. Thus, this pathway rated low with reasonable uncertainty.

Summary

The pathways fall into the following levels of probability of establishment:

High

- Propagative material in air passenger and crew baggage from foreign areas
- Yachts

Moderate

- Aboveground consumption material in cargo or passenger baggage
- Propagative material in cargo
- Cargo ships

Low

- Cruise ships
- Underground plant parts in cargo
- Private aircraft
- Underground plant parts in passenger baggage
- Natural spread

Consequence of Establishment

The expert group decided to consider the consequence of establishment for four "areas." Because the flora, ecology, and socio-cultural conditions may affect consequences differently, the panel considered the United States as a whole, and Florida, Puerto Rico, and U.S. Virgin Islands individually. The expert group discussed the following factors in rating potential economic, environmental, and social/political impact.

Economic Damage Potential

PMB appears to occupy a tropical and subtropical range. The natural range will probably follow citrus growing areas of the tropical and subtropical zones in the U.S. Virgin Islands, Puerto Rico, Florida, Louisiana, Texas, Arizona, and California, and possibly extend to noncitrus areas in the very mild temperate zones of southern Mississippi, Alabama, Georgia, and South Carolina. (Although PMB appears to occupy latitudes roughly between 20° N and S, local differences in elevation and climate make the use of latitudes less reliable than using climatic growing zones as possible determinants of range.)

This pest has been reported in the literature as causing concern only in India and Egypt and currently the Caribbean. Although PMB did not cause losses to agricultural crops in Egypt, it did cause severe losses to landscape and fruit trees and to ornamentals there (Hall 1926).

Some losses to agricultural crops in the Eastern Hemisphere include citrus, cotton, and grapes. No reports of PMB as a major pest of citrus occur in the literature examined, but it has caused some problems. Williams (1985) noted that it caused bunchy leaves on lime in Australia. Reports of serious losses to cotton have been few. In one report, *Maconellicoccus* sp. caused 55 and 69 percent reduction in two arboreum cultivars of seed cotton in India (Dhawan et al. 1980). PMB and another mealybug species were serious pests on weakly growing cotton species that had to be grown as perennials for another experiment (Fletcher 1919, Misra 1920a). Cotton in Egypt was severely infested where the fields were near heavily infested trees or shrubs that served as a reservoir of infestation early in the growing season (Hall 1926). Losses in grapes ranged up to 90 percent in India (Manjunath 1985), but attack of vines in Egypt was not serious, perhaps due to yearly pruning (Hall 1921).

In the Caribbean region, Grenada has suffered extensive damage to agriculture, forestry, horticulture, and the environment. Large numbers of forest and fruit trees, shrubs, vegetables, grasses, weeds, and root crops are involved (Programme Management Committee 1995). The Inter-American Institute for Cooperation on Agriculture projects crop losses for 1995–97 to

run about US$1.8 million a year. Estimates of annual costs due to deleterious effects on the economy, society, and the environment are between US$3.5 million (Francois 1996, cited by Jorge and Castleton 1996) and over US$10 million (Programme Management Committee 1995).

Major losses in Grenada have occurred for *Annona* spp., *Spondias* spp., sorrel, okra, and mango (Pollard 1995b). Many large saman trees have died. PMB infested blue mahoe trees and about 4 acres of teak, each area leading into forests. Of the traditional economic crops, cacao is the most severely affected with production 30 percent less in infested areas (Francis-Ellis 1995).

If PMB were to invade agricultural and forested areas in Trinidad, estimated potential loss could exceed US$125 million annually. Crops at risk include sugarcane, teak, vegetables, ornamentals, orchard crops, cacao, and a germplasm bank. In St. Kitts, PMB particularly threatens the sugar and domestic food crop industries (Programme Management Committee 1995).

As to exports, Grenada's exports of fruits and vegetables to Trinidad and Tobago almost came to a standstill until Grenada could demonstrate their produce was pest free (Francis-Ellis 1995).

PMB will probably not be a risk as a vector of a disease agent. Mealybugs, in general, are unknown to rare as vectors of disease agents (Meyerdirk and Hamon (J)). Although PMB is suspected as a vector of a virus, no infectious agent has been identified in the literature. This mealybug is known to inject a toxin during its feeding; viruslike symptoms appear shortly after.

Although Hawaii also has tropical vegetation, PMB's establishment there has had little or no impact, probably due to introduction of an encyrtid parasite *Anagyrus kamali* Moursi at the same time (Beardsley 1985). The expert group has assumed that effective bio-control agents, however, will not be present in the U.S. Virgin Islands, Puerto Rico, or Florida.

Its very wide host range (E9) and difficulty of control increase the chances that PMB may cause economic loss. Losses in the Caribbean suggest PMB could be an extremely damaging pest for the United States. Risk in the United States is high for ornamental, tree fruit (avocado, citrus, subtropical tree fruit) and for ornamental foliage plants farther north in malls and greenhouses. Potential for economic damage, therefore, is high and MC for the following crops:

- Significant damage is highly likely for avocado, mango, tropical fruit, and ornamentals.

- Damage to some degree will probably occur to citrus, some grape, and summer vegetables grown during the winter and spring in southern areas.

- Damage is possible for cotton but questionable.

Also economic losses from interstate or international restrictions would probably occur if the United States were to become infested. For example, if California or Florida were to become infested, that State would suffer losses because other U.S. areas or foreign countries would prohibit or restrict imports of the products. Products in infested areas would incur costs for treatment if that were required as a condition of entry to importing areas. The exact impact is difficult to assess.

Non–$S Environmental Damage Potential

Deforestation in Grenada threatens some of the important watersheds (Programme Management Committee 1995). PMB infests 71 watersheds between 75 acres to 11,000 acres in size (Francois 1996, cited by Jorge and Castleton 1996). Because of its wide host range, difficulty to control, and many reported dying trees leading to deforestation and erosion, PMB could pose a similar environmental threat to our forests and wild areas.

Establishment of PMB in the United States would threaten the ecosystems of rain forests in Puerto Rico and the U.S. Virgin Islands and of The Everglades National Park in Florida, as well as the endangered species in these areas. Also, environmental concerns would probably restrict if not prevent the use of pesticides in wild areas, allowing PMB if unchecked to spread freely and wild areas to become a natural reservoir for infestations.

Political/Social Impact

As reported in Egypt, heavy infestations of PMB render ornamental gardens and avenues of trees unsightly, bringing it before the public eye and leading them to believe it is more dangerous than it is (Hall 1926). Grenada has experienced a similar impact.

Widespread infestations here would probably result in concerned calls from the citrus industry, environmental groups, truck farmers, the North American Free Trade Agreement (NAFTA) group, the nursery industry, hotels and parks, and homeowners.

Summary

The consequences of establishment of PMB in the United States, Florida, Puerto Rico, and U.S. Virgin Islands were high for all four "areas" because of the high potential for economic loss to tropical and subtropical hosts in urban and rural environments, particularly to tree fruits and ornamentals with some damage to citrus, grape, and summer vegetables. Economic losses would occur from loss in sales and treatment costs in interstate and international markets. Potential for environmental damage to the ecosystems of rain forests and national parks was also rated high. Damage in Florida, Puerto Rico, and U.S. Virgin Islands will be perceived as high by environmental, horticultural, and public groups. Table 3 summarizes the consequence ratings by the expert group.

Table 3. Summary of Consequences of Establishment*

Risk to	Economic damage potential	Non–$$ environmental damage potential	Perceived damage	Consequence rating
United States	H (MC)	M (MC)	M (MC)	H (MC)
Florida	H (MC)	H (MC)	H (MC)	H (MC)
Puerto Rico	H (MC)	H (MC)	H (MC)	H (MC)
U.S. Virgin Islands	H (MC)	H (MC)	H (MC)	H (MC)

* H stands for high potential, M for moderate potential, with MC for moderate certainty.

Risk Management Options—Recommended for Agriculture Quarantine Inspection Activities

1. PPQ workunits at ports in Florida, Puerto Rico, and the U.S. Virgin Islands should:

   - Determine which foreign flight arrivals at their ports carry (or may carry) passengers from islands known to be infested.

   - For passenger baggage from the Caribbean islands known to be infested (Grenada, St. Kitts, and Trinidad)

     - Increase the percentage of inspections.

     - Do *not* rely solely on x rays to clear baggage. (Visual inspection will be needed to detect propagative and other high-risk material.)

     - Clear no propagative material on the baggage floor. (It should be sent to the inspection station or abandoned.)

     - Carefully inspect all baggage lots of permitted fruits, vegetables, and cut flowers. If infested by adults or nymphs, the material should be held or seized, and the mealybugs submitted for identification.

   - For passenger baggage from the noninfested Caribbean islands and Venezuela, carefully inspect permitted or nonpermitted consumption and propagative material for mealybugs. Material infested by adults or nymphs should be held or seized, and the mealybugs submitted for identification.

   - For cargo from the Caribbean islands known to be infested

     - Increase inspection of cut flower, fruit, and vegetable shipments for mealybugs.

     - Inspect personal effects and household goods for mealybugs (adults, young, or eggs) on host material and yard equipment.

     - Carefully clear small cargo boats in the U.S. Virgin Islands from St. Kitts or other infested islands. Extensively inspect fruits, vegetables, and their containers.

   - For cargo from the noninfested Caribbean islands and Venezuela, inspect more carefully than normal for mealybugs in all fruit, vegetable,

cut flower, and plant shipments. If adults or nymphs infest the material, hold the material and submit the mealybugs for identification.

- Board and inspect yachts and sports fishing boats from islands known to be infested. The workunits should formally request that the U.S. Customs Service notify PPQ on the arrival of these boats. [One of the analysts (C.E. Miller) believes yachts from South or Central America should also be boarded because of Medfly (*Ceratitis capitata*) and other serious pests. Total number of all these yachts would be small.]

- Evaluate the risk of cruise ships by using PPQ dog teams to clear baggage from ships that visited infested islands.

2. PPQ in Miami should:

- Assess the risk from "express carrier" packages after the current information survey is completed on this pathway.

- Conduct in the near future an information survey on foreign mail to determine the risk from PMB and other pests.

3. PPQ's Florida State Health Director and the Florida Division of Plant Industry should:

- Reassess the risk of cargo from infested areas being smuggled from Canada if Mexico, Haiti, the Dominican Republic, or Jamaica becomes generally infested.

- Determine how to implement compliance agreements with yacht yards receiving boats from foreign areas. (Yacht yards under compliance agreement in California control garbage and notify persons on the boats of quarantine regulations.)

4. PPQ's Southeastern Regional Office should:

- Ensure that inspection stations can under current authority require precautionary insecticidal dips as well as inspection of plants from the infested islands. Then, direct their inspection station to use insecticidal dips if no PMB is found and the material is destined to remain in Puerto Rico, the U.S. Virgin Islands, and the southernmost tier of States excluding New Mexico and including South Carolina and Georgia. Or to fumigate if PMB is found on material destined to any U.S. area.

- Have selected regional/State participants of this current assessment reexamine pathways in 6 months to determine the need to modify risk estimates or risk management methods.

- Mandate an intensive educational campaign on PMB risk to ensure that port personnel understand the seriousness of PMB entering U.S. areas.

5. International Services (IS), Riverdale, should:

   - Notify PPQ (Riverdale, MD, and the southeastern region) as soon as possible of new country or island records of PMB.

   - Notify IS employees in Bahamas and Bermuda preclearance to be on the alert for possible in-transit persons from infested islands.

6. PPQ, Riverdale, should *not* change the regulatory entry requirements of the host material from the infested area unless additional evidence surfaces of risk from cargo. An example of significant additional evidence would be multiple interceptions of PMB from cargo. Examples of regulatory actions that might be considered at that time are listed in the last section under options not currently recommended.

Recommended for Domestic and Emergency Program Activities— Survey

1. PPQ and State Cooperators in FL, PR, and USVI should piggyback on current survey activities (e.g., citrus canker survey, Cooperative Agricultural Pest Survey (CAPS) program) to increase the probability of early detection of PMB.

2. PPQ and Legislative Public Affairs (Riverdale) should produce a color information handout on PMB to distribute to Federal and State inspection personnel.

3. PPQ Identifiers (Regional or National) should support foreign survey activities by providing identification support when possible.

4. PPQ Identifiers (Regional or National) should determine to generic level, if possible, immature mealybugs from infested or suspect areas (including Agriculture Quarantine Inspection (AQI) material).

5. IS (Riverdale) should actively cooperate with Mexico and with Caribbean countries in the detection and management of this pest.

Biological Control

Phase 1—International Program Initiative

- Target the Leeward Islands of the Lesser Antilles for the development of a classical biological control* program for PMB with initial activity in St. Kitts. Base environmental documentation on the "Dossier on *Anagyrus kamali* Moursi: Biological Control Agent for the Pink Mealybug, *Maconellicoccus hirsutus*, in Trinidad and Tobago" by A.E. Cross and J.S. Noyes [1996], International Institute of Biological Control, Berkshire, UK.

- PPQ and IS, plus USDA, Agricultural Research Service (ARS) will develop a cooperative effort with interested parties such as: the Leeward Islands and Grenada, Tobago, Trinidad; International Institute for Biological Control (IIBC); Inter-American Institute for Cooperation on Agriculture (IICA); Caribbean Community (CARACOM); Caribbean Forum of ACP States (CARFORM); Food and Agricultural Organization (FAO); and Caribbean Agriculture Research and Development Institute (CARDI).

- Import exotic natural enemies of PMB from Grenada, Hawaii, Egypt, and central parts of Africa for release and establishment in the Leeward Islands.

- Quarantine and screen all natural enemies at the USDA, APHIS, PPQ Biological Control Quarantine Facility in Mission, Texas.

- Ship all adult exotic parasites cleared and permitted for release to St. Kitts for culturing and/or direct field release.

- Continue to rear natural enemies in the laboratory and/or field for collection and redistribution efforts in St. Kitts.

- Evaluate establishment and impact of releases on PMB.

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* Classical Biological Control is based on the importation and release of exotic natural enemies (parasites, predators, pathogens, or antagonists) and their long-term establishment in the new environment, which may then provide continuing control of the introduced exotic pest arthropod or weed.

Phase 2—National Program Initiative: Undertake Phase 2 upon establishment of PMB on the U.S. Virgin Islands, Puerto Rico and/or the continental United States.

- Transfer all exotic natural enemies of PMB in culture and/or established in St. Kitts and/or other Leeward Islands to the U.S. Territories and/or States that become infested for release and establishment.

- Develop cooperative efforts with governments of all newly invaded land masses.

- Continue to cooperate with other Caribbean islands to provide exotic natural enemies for establishment.

- Set up laboratory cultures for further propagation and release in infested areas. (Utilize the Brown Citrus Aphid Quarantine Facility in Puerto Rico if applicable.)

- Evaluate establishment and impact of releases on PMB.

- Develop sex pheromone traps for monitoring the PMB's population density.

Contingency Planning

PPQ, Riverdale, should complete development of the new pest response guidelines, send it to concerned parties for review, and then distribute it.

Options Considered but Not Currently Recommended

1. Require Phytosanitary Certification for

   - Cargo that was inspected and found free of PMB for fruits, vegetables, cut flowers, and live plants

   - Shipment and growing area that were inspected and found free of PMB for fruits, vegetables, cut flowers, and live plants

   - Insecticidal dip required for live plants

   - Packing houses (and shipping containers) that are free of infestation or contamination

- Shipping containers are new

2. Require fumigation at port of entry as a condition of entry for all or certain products or plants.

3. Require insecticidal dip for live plants at port of entry.

4. Require pest-free area (Tobago) in lieu of some of the above.

Conclusions

In general, the presence of PMB in the Caribbean represents a high risk situation for Florida, Puerto Rico, and the U.S. Virgin Islands The expert group agrees that this pest will become established in the southeastern United States in the near future. PMB will affect interstate and international trade as well.

The assessment identified high risk pathways as stores on yachts and sport fishing boats and as propagative material in air passenger and crew baggage. Pathways of more moderate risk were identified as above ground consumption material carried as cargo and in air passenger baggage, propagative material in cargo, and cargo ships (stores, quarters, holds, garbage, and crew baggage). All other pathways were considered low risk: cruise ships, private aircraft, underground plant parts in cargo or in air baggage, and natural spread.

Increased risk management for the high and moderate risk pathways should slow down the spread of PMB into the United States but is not likely to stop the spread. The lack of a known effective chemical control and an inability to eradicate this type of pest once it is well established will aid in its spread.

The expert group concludes that a major component of effectively managing this pest will be biological control. With APHIS active involvement in biological activities at this time, effective bio-control agents could be introduced into the current explosive populations of this pest in the Caribbean. This involvement would have a two-fold benefit for the United States. First, PMB populations could be drastically reduced in the non-U.S. Caribbean area, which would greatly reduce the rate of spread of this pest into the United States. Second, involvement would aid in the development of the only long-range, effective pest management tool for us before this pest establishes in the United States.

Appendix 1: Assessment Codes

Key to Codes

Reference types

Code	Type
(G)	General knowledge, no specific source
(J)	Judgmental evaluation
(E)	Extrapolation. Information specific to pest is unavailable; information on similar organism was applied.
(Author year)	Literature cited

Risk Ratings

Code	Level
H	High
M	Medium
L	Low

Uncertainty Codes

Code	Level
VC	Very Certain: as certain as I'm going to get
RC	Reasonably Certain
MC	Moderately: more certain than not
RU	Reasonably Uncertain
VU	Very Uncertain: a guess

Determine Final Ratings

Determine probability of establishment: After each element (pest with host, entry, colonization, spread) is rated for a pathway, the probability of establishment assumes the lowest rating of the four elements. For example, a high—low—medium—medium results in a low probability of establishment.

Determine consequence of establishment: After each element for the pathway (economic, environmental, perceived) is rated, the consequence of establishment assumes the highest rating of the economic or environmental elements. A medium—low—high, respectively for the three elements, results in a medium consequence of establishment. When both economic and environmental are rated low, the consequence of establishment assumes the lowest rating assigned to the perceived element.

Determine Pest Risk Potential (PRP) from Probability of Establishment and Consequence of Establishment: When ratings are adjacent in risk levels, use the higher risk (e.g., L and M = M). When levels are not adjacent, use the middle level (e.g., L and H = M).

Rating Definitions for Pest Risk Potential

H = unacceptable risk—organisms of major concern, either mitigate or regulate

M = unacceptable risk—organisms of moderate concern, either mitigate or regulate

L = acceptable risk—organisms of little concern, does not justify mitigation or regulation

Appendix 2: The Evidence

E1. Interceptions of *Maconellicoccus hirsutus* by PPQ, 1985–95

Host	Baggage	Permit Cargo	Quarters
Annona sp.	6		
Annona cherimola (Fruit)	10		
Annona muricata (Fruit)	4		
Annona reticulata (Fruit)	2		1
Annona squamosa (Fruit)	28		
Annona squamosa (Dried Fruit)	1		
Averrhoa carambola (Fruit)	1		
Citrus sp. (Fruit)—**Australia to CA**		1	
Dimocarpus longan (Fruit)	2		
Durio sp. (Fruit)—**Thailand to CA**		1	
Durio zibethinus (Fruit)— **Thailand to CA**		2	
Eriobotrya sp. (Leaf)	1		
Garcinia mangostana (Fruit)	2		
Hibiscus sp.	1		
Hibiscus sabdariffa (Fruit)	1		
Lansium domesticum (Fruit)	2		
Litchi chinensis (Fruit)	1		
Nephelium lappaceum (Fruit)	14		2
Persea americana (Leaf)	1		
Psidium sp. (Fruit)	1		
Psidium guajava (Fruit)	9		
Spondias sp. (Fruit)	1		
Undetermined species (Fruit)	1		
Undetermined species (Dried Material)	1		
Dactyloctenium aegyttium (Contaminant)—**Mexico to CA**		1	
Total	**90**	**5**	**3**

Source: PINET Database, CY 1985-95.

Locations in bold indicate interceptions in cargo.

Notes for E1:

1. Country of origin for baggage or quarters' interceptions (with number intercepted): Asia (7), Bangladesh (2), Brazil? (1), China (1), Ghana (1), Hong Kong (2), India (9), Indonesia (3), Malaysia (1), Philippines (12), Republic of China (6), Saudi Arabia (1), Singapore (4), Thailand (9), Unknown (8), Vietnam (25) and Zambia (1).

2. State of destination for baggage interceptions (with number intercepted): CA (44), FL (2), GA (1), LA (1), TX (2), and Northern States of DC, DE, IL, KS, MA, NJ, NY and WA (32).

3. Intercepted from *Dactyloctenium* (Egyptian grass) contaminating a shipment of basil from Baja California, Mexico. This is a new country record and was identified by Entomologist Doug Odermatt, Beltsville, Maryland, BATS, PPQ. Tim Torbett, Area Botanist, PPQ, intercepted it on August 15, 1995, at San Francisco, CA.

4. A review of 51 records of PMB intercepted FY1971-84 produced similar host and country data as recorded above. One baggage intercepted from the Philippines on *Musa* sp. (Fruit) is of interest.

D. Odermatt, BATS, PPQ, also located two unusual interceptions in the National Museum of Natural History collection at Beltsville, MD. Their associated PPQ Form 309s revealed the following information. The origins could not be confirmed, so these countries cannot be considered infested.

Host	Situation	Origin	Year	Destination
Annona muricata (Fruit)	Once in baggage	Dominican	1983	NY
Persea americana (Leaves)	Once in baggage	Republic Panama	1992	CA

The California Department of Food and Agriculture has records of six *M. hirsutus* interceptions since 1991. Thanks to Raymond J. Gill for the following information.

Host	Border station	Quarantine	Grocery
Dimocarpus longan	4		1
Ginger flower		1	

Probable origin: Asia 4, Hawaii 1, Thailand? 1
Locale of interception: WA 2, CA 2, British Colombia 2

E2. Interceptions of Mealybugs Identified to Family Level Only (sp. of Pseudococcidae) from the PMB-Infested Area

Origin/Host	Times Intercepted/at/Imported as
Grenada - Artocarpus altilis (Fruit)	Once at Miami in Cargo
- Calathea sp. (Leaf)	Once at Honolulu in Cargo
- Capsicum sp. (Fruit)	Once at Miami in Cargo
St. Kitts	None
Trinidad and Tobago - Theobroma cacao (Fruit)	Once at Miami in Cargo

Source: PINET Database, CY 1985-95.

E3. Miami Mealybug Interceptions on Cargo from Grenada, 03/01/96 to 04/26/96*

Host	Taxon
mango/breadfruit	Pseudococcidae (nymph)
pepper	*Dysmicoccus brevipes*
breadfruit	*Dysmicoccus brevipes*
breadfruit	*Pseudococcus longispinus*
breadfruit	Pseudococcidae (nymph)
mango	Pseudococcidae (nymph)
mango	Pseudococcidae (nymph)

* This was the result of a request that cargo from Grenada and Trinidad would be given a more careful inspection and to target mealybugs. A total of 27 shipments from Trinidad and 45 shipments from Grenada were inspected.

Source: T. T. Dobbs, Entomology Identification, Miami, and Jeff Bruff, SPPO, Miami.

E4. Cargo Imports from Grenada, FY 1994

Import category - Host	Host	U.S. port	Shipments	Amount
Propagative Material				
- Misc. Palms (seed)	**H**	**Miami**	**1**	**10 kg**
- Misc. Permit Seeds	**-**	**Miami**	**1**	**1 kg**
- Syzygium sp.	**H**	**Miami**	**1**	**1 plant**
Cut Flowers				Stems
- Anthurium	**H**	**Miami**	**1**	**4,200**
- Cut Flower		JFK	11	239
Fruit and Vegetables				kg
- Amaranthus	H	JFK	1	50
- Asparagus	**H**	**Miami**	**2**	**3,300**
- Avocado	**H**	**Miami**	**114**	**5,823**
		BWI, Dulles, JFK	59	14,004
- Banana	**H**	**Miami**	**1**	**40**
		JFK	43	11,613
- Bilimbi	H	JFK	1	173
- Blackberry	**N**	**Miami**	**1**	**4,670**
- Breadfruit	**H**	**Miami**	**256**	**21,693**
		BWI, Dulles, JFK	50	11,174
- Breadnut	H	JFK	19	3,258
- Citrus	H	JFK	7	630
- Clusterbean	N	BWI	1	195
- Coconut	H	JFK	9	1,020
- Cucurbit	H	JFK	3	576
- Dasheen	**H**	**Miami**	**2**	**400**
		JFK	19	1,514
- Dasheen leaves	**H**	**Miami**	**14**	**740**
		BWI, JFK	30	1,904
- Eggplant	H	JFK	1	80
- Genip	**H**	**Miami**	**2**	**78**
		San Juan	**1**	**68**
		BWI	1	1,004

See footnotes at end of table.

E4. Cargo Imports from Grenada, FY 1994—Continued

Import category - Host	Host	U.S. port	Shipments	Amount
Fruit and Vegetables (con.)				kg
- Governor's Plum	**H**	**Miami**	**5**	**11,936**
		JFK	38	28,100
- Grapefruit	**H**	**Miami**	**1**	**150**
- Lemongrass	**N***	**Miami**	**1**	**162**
- Mamey	N	JFK	4	155
- Mango (?)	**H**	**Miami**	**82**	**38,971**
		BWI, Dulles, JFK	180	136,849
- Mango leaves	H	JFK	1	5
- Papaya	H	BWI, JFK	12	1,212
- Passion fruit	**H**	**Miami**	**2**	**135**
		JFK	5	29
- Pepper	**H**	**Miami**	**25**	**11,759**
		BWI, Dulles, JFK	90	13,789
- Pigeon pea	H	JFK	7	3,460
- Plantain	**H**	**Miami**	**1**	**2,260**
- Raspberry	**N**	**Miami**	**1**	**4,130**
- Sorrel	H	BWI, JFK	6	2,410
- Spondias spp.	**H**	**Miami**	799	**88,972**
Incl. Golden-apple, Ambarella, Spanish-plum, Hog-plum, mombin, Jobo, and Jocote		BWI, Dulles, JFK	179	215,808
- Tamarind	**H**	**Miami**	**1**	**10**
		JFK	30	8,415
- Thyme	N	JFK	1	3
- Tomato	**H**	**Miami**	**1**	**113**
- Yam	**H**	**Miami**	**1**	**80**

Bold marks cargo arriving at Southeastern ports.
H indicates a species reported as a host in the Caribbean or the Old World; N indicates those that have not been reported as host.
* PPQ has intercepted once from this species. See interceptions.

Cargo source: Monthly Report of Regulated Articles, Port Operations, PPQ, Riverdale, MD.

E5. Cargo Imports from St. Kitts and Nevis, FY 1994

Import category - Commodity	Host	U.S. port	Port type	Shipments	Amount
St. Kitts					
Cut Flowers					Stems
- Alpinia	**H**	**St. Croix**		**1**	**205**
- Anthurium	**H**	**St. Croix**	**A**	**3**	**1,185**
- Dracaena	**H**	**St. Croix**	**A**	**1**	**95**
- Heliconia	**H**	**St. Croix**	**A**	**1**	**10**
Fruit and Vegetables					kg
- Breadfruit	**H**	**St. Croix**	**A**	**1**	**15**
- Cabbage	**N**	**St. Croix**	**A**	**1**	**20**
- Mango	**H**	**St. Croix**	**A**	**3**	**22**
- Melon	**H**	**St. Croix**	**A**	**1**	**30**
- Peanut	**H**	**St. Croix**	**A**	**5**	**80**
- Plantain	**H**	**St. Croix**	**A**	**1**	**10**
- Pumpkin	**H**	**St. Croix**	**A**	**1**	**40**
- Sweet potato	**H**	**St. Croix**	**A**	**2**	**45**
- Yam	**H**	**St. Croix**	**A**	**1**	**25**
*Nevis**					
Cotton/Cotton Products					kg
- Cotton from Nevis	H	West Palm Beach in transit	M	1	2,179

Bold marks cargo arriving at Southeastern ports.

H indicates a host reported in the Caribbean or the Old World; N indicates those that are not.

* Nevis, a sister island of St. Kitts, is not infested.

Port type: A air vs. M maritime

Cargo source: Monthly Report of Regulated Articles, Port Operations, PPQ, Riverdale, MD.

E6. Cargo Imports from Trinidad and Tobago, FY 1994

Import category - Host	Host	U.S. port	Shipments	Amount
Propagative Material				
- Orchid	**H ?**	**Miami**	**2**	**121 plants**
		San Juan	**1**	**8 plants**
-Tropical Foliage	**-**	**Miami**	**2**	**36 plants**
- Misc. Reg. Seeds	-	JFK	1	2 kg
Cut Flower				Stems
-Alpinia	**H**	**St. Thomas**	**9**	**63**
-Alstromeria	**N**	**Miami**	**4**	**4,800**
-Anthurium	**H**	**Miami**	**47**	**234,540**
		St. Thomas	**17**	**997**
- Bouquet	**-**	**Miami**	**1**	**1,500**
- Cut Flower	-	JFK	151	2,323
- Dianthus	**N**	**Miami**	**1**	**22,800**
- Lilium	**N**	**Miami**	**2**	**7,920**
- Orchid	**H ?**	**Miami**	**3**	**8,280**
- Rosa	**H**	**St. Thomas**	**16**	**128**
		Miami	**1**	**2,700**
Fruit and Vegetables				kg
- Amaranthus	H	JFK	1	351
- Banana	H	JFK	7	920
- Bean, Green	H	JFK	30	2,714
- Bean, Yard Long	N	BWI	5	279
- Bitter Melon	N	BWI, JFK	5	881
- Breadfruit	H	JFK	136	45,312
- Coconut	H	JFK	1	20
- Coriander	N	BWI, JFK	470	281,790
- Cucurbit	H	Dulles, JFK	42	79,168
- Dasheen	H	BWI, JFK	56	25,000
- Dasheen leaves	H	BWI, JFK	157	82,122
- Eggplant	H	JFK	34	9,311

See footnotes at end of table.

E6. Cargo Imports from Trinidad and Tobago, FY 1994—Continued

Import category - Host	Host	U.S. port	Shipments	Amount
Fruit and Vegetables (con.)				kg
- Ginger	**N**	**St. Thomas**	**5**	**41**
- Lemon	H	JFK	3	506
- Mango	H	JFK	1	123
- Mangosteen	N	JFK	2	1,700
- Okra	H	BWI, JFK	6	104
- Palm leaves	**H**	**St. Thomas**	**1**	**11**
- Papaya	H	BWI, JFK	85	34,139
- Pepper	H	BWI, Dulles, JFK, Elizabeth	327	158,501
- Pigeon pea	H	JFK	1	180
- Pineapple	N	JFK	2	205
- Pumpkin	H	BWI	2	2,756
- Shallot	N	Elizabeth	1	12,050
- Sorrel	H	JFK	5	711
- Tamarind	H	BWI	1	23

Bold marks cargo arriving at Southeastern ports.

H indicates a host reported in the Caribbean or the Old World; N indicates those not reported as a host. A 'H?' means that other species in its group are specified as hosts in the literature, but this species is not listed.

Cargo source: Monthly Report of Regulated Articles, Port Operations, PPQ, Riverdale, MD.

E7. Monthly Fruit and Vegetable Imports from Grenada, FY 1994

Host	Kilograms											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Amaranthus								50				
Asparagus										3,300		
Avocado	8,935	1,491	651					317	521	4,026	269	3,617
Banana	1,808	1,240	1,107	420	1,107	1,769	555	1,862	411	310		1,064
Bilimbi										173		
Blackberry*			4,670									
Breadfruit	7,532	1,177	1,761	2,370	4,839	6,001	184	564	3,874	1,295	110	3,160
Breadnut	1,000					47	422	324	626			839
Citrus	100		199	60	199	72						
Grapefruit				150								
Clusterbean*										195		
Coconut	136	120	250		250		27	41		136		60
Cucurbit									576			
Dasheen		25	160	480		104		204	190	518		233
Dasheen leaves	648	174	227	183	76	104	97	148	233	131	15	608
Eggplant									80			
Genip	33									1,117		
Governor's plum	2,820	2,664		2,356				245	135	10,920	3,233	17,663
Lemon-grass †									162			
Mamey *								130	25			
Mango	1,426	642	1823	3,730	3,242	38,434	18,976	23,772	34,619	35,482	4,851	8,823
Mango leaves	5											
Papaya	214	322	165		100			187	157	27		

See footnotes at end of table.

E7. Monthly Fruit and Vegetable Imports from Grenada, FY 1994—Continued

Host	Kilograms											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Passion fruit	20								136		3	5
Pepper	5,418	2,192	3,139	3,249	2,227	1,104	524	1,465	2,605	1,199	1,883	543
Pigeon pea			1,285	814	1,285	76						
Plantain												2,260
Raspberry *			4,130									
Sorrel			805	70	1,535							
Spondias spp.												
Ambarella	13,459	3,100		230								
Golden apple	10,345		8,744			40			110	6,621	3,522	2,270
June plum	20,360		1,389	770								
Mombin	65,039	68,271	1,534	1,034		105		197		10,859	10,875	34,908
Plum	694		10,509						297		2,625	27,077
Tamarind			1,560		1,560	2,490		2,785	30			
Thyme *		3										
Tomato												113
Yam			80									

* Not reported as a host in the Caribbean or the Old World.

† also not reported as a host, but PPQ made one interception. See interceptions.

Source: Monthly Report of Regulated Articles, Port Operations, PPQ, Riverdale, MD.

E8. Air Traffic from the PMB-infested Caribbean area to U.S. ports*

Arrival Area	Arrival Port	From†	Flights/ week	Airline
Florida	Miami	Grenada	1	AmeriJet International
			2	BWIA International (BW)
		Port of Spain	7	AmeriJet
			7	American Airlines (AA)
			20	BW
		St. Kitts	2	AmeriJet
	Miami (San Juan?)	St. Kitts -Antigua	7	AA
	Miami ?	-Antigua	4	BW
	Orlando International (Miami ?)	St. Kitts -St. Maarten	7	AA
Total			57	
Maryland	Baltimore Washington International	St. Kitts -St. Maarten	2	USAir
Total			2	
New York	J.F. Kennedy International	Grenada	1	BW
		Port of Spain	22	BW
		St. Kitts -Antigua	2	BW
Total			25	
Puerto Rico	San Juan	Grenada	8	AA
			7	Liat Ltd. (LI)
		Port of Spain	7	AA
			2	LI
		St. Kitts -St. Maarten	7	AA
		St. Kitts	28	AA

See footnotes at end of table.

E8. **Air Traffic from the PMB-infested Caribbean area to U.S. ports*—Continued**

Arrival Area	Arrival Port	From†	Flights/ week	Airline
Puerto Rico (con.)	San Juan (con.)	St. Kitts (con.)	7	LI
Total			66	
U.S. Virgin Islands	St. Thomas	Grenada -Antigua	1	LI
		-Antigua	7	LI
		Port of Spain -Antigua	7	LI
		St. Kitts	17	LI
	St. Croix	Grenada -Antigua	7	LI
		Port of Spain -Anguilla	1	Coastal Air Transport
		-Antigua-St. Maarten	7	LI
		Saint Kitts	7	LI
Total			54	

* Mention of company names does not imply recommendation or endorsement by the U.S. Department of Agriculture over others not mentioned. USDA neither guarantees nor warrants the standard of any company mentioned. Companies are mentioned solely to report factually on available data and to provide specific information.

† Hyphenated locations are known connecting flights. For example, the second St. Kitts flight arriving in Miami connected to St. Kitts (infested) and then to Antigua (noninfested) before arriving in Miami.

Flights per week in bold type appear as a sample of commercial cargo flights for Miami. Numbers not in bold are passenger flights. J. Bruff contributed the information from AmeriJet International.

Source: OAG Official Traveler (TM) FlightDisk (R)Worldwide edition. [for] February 1 to March 14, 1996. Official Airline Guides, Reed Elsevier Inc. Copyright 1995.

E9. Plants Infested by *Maconellicoccus hirsutus**

Botanical Name	Common Names	Carib.			E	Pref.		Use	Family
		G	K	T		C	E		
Abelmoschus esculentus	Ochro, okra	G	K	T	E	1	1	V	Malvaceae
Aberia					E				Flacourtiaceae
Abutilon avicennae = *A. theophrasti*									Malvaceae
Abutilon theophrasti					E		2		Malvaceae
Acacia sp.	Acacia			T	E		2		Fabaceae
Acacia arabica = *A. nilotica*									Fabaceae
Acacia farnesiana					E		2		Fabaceae
Acacia nilotica					E		1		Fabaceae
Acalypha spp.					E		2		Euphorbiaceae
Acalypha hispida	Cat's tail	G	K	T		1		O	Euphorbiaceae
Acalypha indica					E		2		Euphorbiaceae
Acalypha marginata					E		2		Euphorbiaceae
Acanthus ilicifolius					E				Acanthaceae
Achyranthes indica	Man better man			T				W	Amaranthaceae
Acocanthera					E				Apocynaceae
Adina cordifolia = *Haldina cordifolia*									Rubiaceae
Aegle marmelos	Bael			T					Rutaceae
Aglaonema sp.	Silver queen			T					Araceae
Albizia caribaea = *A. niopoides*									Fabaceae
Albizia lebbek					E		1		Fabaceae
Albizia niopoides	Tantakayo	G				1		Fo	Fabaceae
Albizia saman	Saman	G		T		1		O/ Fo	Fabaceae
Allamanda spp.*	Allamanda	G				2		O	Apocynaceae
*Allamanda cathartica**	Yellow buttercup			T					Apocynaceae
Alocasia cucullata	Heart shae dasheen			T					Araceae
Alpinia spp.	Gingerlily	G		T		1		O	Zingiberaceae
Althaea					E				Malvaceae
Amaranthus sp.	Bhagi	G		T					Amaranthaceae
Annona spp.	Atemoya	G			E	1		Fr	Annonaceae
Annona cherimola					E		3		Annonaceae
Annona muricata	Soursop	G	K	T	E	1		Fr	Annonaceae
Annona reticulata	Custard-apple	G	K		E	1	3	Fr	Annonaceae
Annona squamosa	Sugar-apple	G	K	T	E	1	2	Fr	Annonaceae
Anthurium andraeanum	Anthurium	G				1		O	Araceae
Arachis hypogaea	Peanut				E				Fabaceae

See footnotes at end of table

E9. Plants Infested by *Maconellicoccus hirsutus—Continued**

Botanical Name	Common Names	Carib.			E	Pref.		Use	Family
		G	K	T		C	E		
Aralia spp.	Angelica	G	K		E	1		O	Araliaceae
Artocarpus altilis	Breadfruit or chataigne	G	K	T		1		Fr	Moraceae
Artocarpus communis = *A. altilis*									Moraceae
Asparagus spp.	Asparagus fern	G	K			1		O/V	Liliaceae
Asparagus densiflorus	Rice fern			T					Liliaceae
Asparagus officinalis	Asparagus				E				Liliaceae
Asparagus setaceus	Bridal fern			T					Liliaceae
Averrhoa carambola	Carambola, Five fingers	G	K	T		1		Fr	Oxalidaceae
Azadirachta indica	Neem	G		T		3		O	Meliaceae
Basella alba	Poi spinach	G				1		V	Basellaceae
Bauhinia spp.					E				Caesalpiniaceae
Bauhinia acuminata					E		2		Caesalpiniaceae
Bauhinia candicans = *Bauhinia forficata pruinosa*									Caesalpiniaceae
Bauhinia forficata pruinosa					E		1		Caesalpiniaceae
Bauhinia racemosa					E		2		Caesalpiniaceae
Bauhinia vahlii					E		2		Caesalpiniaceae
Bauhinia variegata	Orchid tree	G			E	1	1	O	Caesalpiniaceae
Begonia sp.	Begonia			T					Begoninaceae
Beta vulgaris	Beet root	G				1		V	Chenopodiaceae
Bidens pilesa	Railway daisy			T					Asteraceae
Bignonia					E				Bignoniaceae
Blighia sapida	Ackee			T					Sapindaceae
Boehmeria nivea	Ramie				E				Urticaceae
Bougainvillea sp.	Bougainvilla	G	K	T		2		O	Nyctaginaceae
Bougainvillea spectabilis					E		2		Nyctaginaceae
Brassaia actinophylla = *Schefflera actinophylla*									Araliaceae
Caesalpinia coriaria	Divi-Divi	G				1		O	Fabaceae
Caesalpinia decapetala					E		2		Fabaceae
Caesalpinia pulcherrima	Pride of Barbados or dwarf poinciana			T					Fabaceae
Caesalpinia sepiaria = *C. decapetala*									Fabaceae
Cajanus cajan	Pigeon pea	G		T	E	1	1	FC	Fabaceae
Cajanus indicus = *C. cajan*									Fabaceae
Calliandra sp.	Powder puff			T					Fabaceae

E9. **Plants Infested by *Maconellicoccus hirsutus**—Continued**

Botanical Name	Common Names	Carib. G	Carib. K	Carib. T	E	Pref. C	Pref. E	Use	Family
Callistemon sp.	Bottle brush tree			T					Myrtaceae
Cananga odorata	Ylang-Ylang	G				1		O	Annonaceae
Capsicum sp.	pepper, Seasoning		K						Solanaceae
Capsicum annum	pepper, Sweet	G	K	T		1		V	Solanaceae
Capsicum fructescens	pepper, Hot	G		T		1			Solanaceae
Carica papaya	Papaya or pawpaw	G	K	T	E		2	Fr	Caricaceae
Carissa acuminata = *C. bispinosa*									Apocynaceae
Carissa bispinosa					E		2		Apocynaceae
Carissa grandiflora = *C. macrocarpa*									Apocynaceae
Carissa macrocarpa					E		2		Apocynaceae
Cassia spp.					E		2		Fabaceae
Cassia glauca = *Senna sulfurea*									Fabaceae
Cassia obovata = *Senna italica*									Fabaceae
Cassia renigera					E		2		Fabaceae
Cassia siamea = *Senna siamea*									Fabaceae
Casuarina sp.	Casuarina			T					Casuarinaceae
Catharanthus roseus	Old maid or periwinkle			T		0		O	Apocynaceae
Ceiba pentandra					E				Bombacaceae
Celosia cristata	Cox comb			T					Amaranthaceae
Ceratonia siliqua	Carob				E		1		Fabaceae
Cestrum nocturnum	Ladies of the night	G				1		O	Solanaceae
Chalcas paniculata = *Murraya paniculata*									Rutaceae
Chenopodium album	Lamb's quarters				E				Chenopodiaceae
Chrysanthemum coronarium					E				Asteraceae
Chrysothemis pulchella	Gesneriad			T					Gesneriaceae
Cissus verticillata	Snake vine			T					Vitaceae
Citrus spp.	citrus species, all Lime, lemon, orange, portugal	G	K	T	E	1		Fr	Rutaceae
Citrus aurantium	Sour orange				E		2		Rutaceae
Citrus bigarradia = *C. aurantium*									Rutaceae
Citrus medica	Citron				E		2		Rutaceae
Citrus nobilis					E		2		Rutaceae

E9. Plants Infested by *Maconellicoccus hirsutus—Continued**

Botanical Name	Common Names	Carib. G	Carib. K	Carib. T	E	Pref. C	Pref. E	Use	Family
Citrus paradisi	Grapefruit				E				Rutaceae
*Clerodendrum aculeatum**	Bitter fence	G	K			2		O	Lamiaceae
Clerodendrum infortunatum					E				Lamiaceae
Clitoria ternatea					E				Fabaceae
Coccoloba uvifera	Seagrape	G		T		1		O	Polygonaceae
Coccus nucifera	Coconut			T					Arecaceae
Codiaeum spp.	Croton	G	K	T		1		O	Euphorbiaceae
Coffea spp.					E				Rubiaceae
Coffea arabica					E				Rubiaceae
Colocasia esculenta	Eddoe, dasheen			T					Araceae
Colubrina arborescens	Mauby, wild coffee	G				1		S	Rhamnaceae
Corchorus sp.					E				Tiliaceae
Corchorus olitorius					E		2		Tiliaceae
Cordia curassavica	Black sage	G		T		1		W	Boraginaceae
Cordyline terminalis	Cordyline			T					Liliaceae
Cosmos spp.	Cosmos	G			E	1		O	Asteraceae
Couroupita guianensis	Cannonball tree	G				1		Fo	Lecythidaceae
Crataegus spp.					E		3		Rosaceae
Crescentia cujete	Calabash tree			T					Bignoniaceae
Croton					E				Euphorbiaceae
Croton flavens	Broom	G				1		W	Euphorbiaceae
Cucumis sativus	Cucumber	G	K			1		V	Cucurbitaceae
Cucurbita maxima	Pumpkin	G		T		1		V	Cucurbitaceae
Cucurbita moschata	Pumpkin			T					Cucurbitaceae
Cucurbita pepo	Squash	G				1		V	Cucurbitaceae
Cydonia oblonga	Quince				E		2		Rosaceae
Cyperus sp.	Sedges			T					Cyperaceae
Dahlia					E				Asteraceae
Datura sp.	Datura, angel's trumpet			T					Solanaceae
Daucus carota	Carrot	G				1		V	Apiaceae
Delonix regia	Flametree				E		3		Fabaceae
Dendrobium cvs.	Orchid	G				3		O	Orchidaceae
Dieffenbachia sp.	Dieffenbachia			T					Araceae
Dioscorea spp.	Yam	G		T		0		RC	Dioscoreaceae
Diospyros kaki					E		2		Ebenaceae
Dizygotheca elegantissima = *Schefflera elegantissima*									Araliaceae
Dracaena sp.	Dracaena			T					Liliaceae
Duranta sp.					E				Verbenaceae

E9. Plants Infested by *Maconellicoccus hirsutus—Continued**

Botanical Name	Common Names	Carib. G	Carib. K	Carib. T	E	Pref. C	Pref. E	Use	Family
Duranta plumieri = *D. repens*									Verbenaceae
Duranta repens	Duranta	G			E	1	3	O	Verbenaceae
Elaeagnus					E				Elaeagnaceae
Emilia sp.	a weed			T					Asteraceae
Eranthemum nervosum = *E. pulchellum*									Acanthaceae
Eranthemum pulchellum				T					Acanthaceae
Eriobotrya japonica	Loquat				E		3		Rosaceae
Ervatamia coronaria = *Tabernaemontana divaricata*									Apocynaceae
Eryngium foetidum	Shadow-beni			T					Apiaceae
Erythrina sp.					E				Fabaceae
Erythrina corallodendrum					E		1		Fabaceae
Erythrina crista-galli					E		1		Fabaceae
Erythrina indica = *E. stricta*									Fabaceae
Erythrina resinifera					E		1		Fabaceae
Erythrina reticulata = *E. speciosa*									Fabaceae
Erythrina speciosa					E		1		Fabaceae
Erythrina stricta					E		1		Fabaceae
Erythrina variegata	Variegated immortelle	G	K		E	1	1	O	Fabaceae
Erythrina vespertilio					E		1		Fabaceae
Eugenia spp.	Wax apple	G			E	1		Fr	Myrtaceae
Eugenia jambolana = *Syzygium cumini*									Myrtaceae
Eugenia malaccensis = *Syzygium malaccense*									Myrtaceae
Euphorbia sp.	Milkweed			T					Euphorbiaceae
*Euphorbia pulcherrima**	Poinsettia			T	E		2		Euphorbiaceae
Ficus benghalensis	Banyan				E		3		Moraceae
Ficus benjamina	Weeping fig			T	E		3		Moraceae
Ficus carica	Fig				E		3		Moraceae
Ficus cunia					E				Moraceae
Ficus elastica	Rubber plant				E		3		Moraceae
Ficus indica = *Ficus benghalensis*									Moraceae
Ficus infectoria = *F. virens*									Moraceae

E9. **Plants Infested by *Maconellicoccus hirsutus**—Continued**

Botanical Name	Common Names	Carib. G	Carib. K	Carib. T	E	Pref. C	Pref. E	Use	Family
Ficus nitida = *Ficus benjamina*									Moraceae
Ficus platyphylla					E		2		Moraceae
Ficus religiosa					E		3		Moraceae
Ficus sycomorus					E		3		Moraceae
Ficus virens					E		3		Moraceae
Flacourtia indica	Series			T					Flacourtiaceae
Gerbera sp.	Gerbera			T					Asteraceae
Gliricidia sepium	Glyricidia	G	K			1		AF	Fabaceae
Glycine max	Soybean	G			E	1		V	Fabaceae
Gossypium spp.					E		1		Malvaceae
Gossypium arboreum					E				Malvaceae
Gossypium herbaceum					E				Malvaceae
Grevillea robusta	Silk-oak				E		1		Proteaceae
Grewia sp.					E				Fabaceae
Haldina cordifolia					E		2		Rubiaceae
Hamelia sp.				T					Rubiaceae
Helianthus annuus					E				Asteraceae
Heliconia spp.	Heliconias	G		T		1		O	Musaceae
Hibiscus spp.					E				Malvaceae
Hibiscus acetosella					E				Malvaceae
Hibiscus boryanus					E				Malvaceae
Hibiscus cannabinus	Mesta, kenaf				E		1		Malvaceae
Hibiscus elatus	Blue Mahoe	G				1		Fo	Malvaceae
Hibiscus esculentus = *Abelmoschus esculentus*									Malvaceae
Hibiscus manihot					E				Malvaceae
Hibiscus mutabilis					E		1		Malvaceae
Hibiscus rosa-sinensis	Hibiscus	G	K	T	E	1	1	O	Malvaceae
Hibiscus rosa-sinensis var. *floreplenis*					E				Malvaceae
Hibiscus sabdariffa					E		1		Malvaceae
Hibiscus sabdariffa var. *altissimus*	Roselle				E				Malvaceae
Hibiscus sabdariffa var. *sabdariffa*	Sorrel	G	K	T		1		FC	Malvaceae
Hibiscus schizopetalus					E		1		Malvaceae
Hibiscus surattensis					E				Malvaceae
Hibiscus syriacus	Rose-of-Sharon				E		1		Malvaceae
Hibiscus tiliaceus					E				Malvaceae
Holmskia sanguinea	Chinese Hat	G				1		O	Malvaceae

E9. Plants Infested by *Maconellicoccus hirsutus—Continued**

Botanical Name	Common Names	Carib. G	Carib. K	Carib. T	E	Pref. C	Pref. E	Use	Family
Inga sp.					E		2		Fabaceae
Ipomoea sp.	Morning glory tree			T					Convolvulaceae
Ipomoea batatas	Sweet potato	G		T		1		RC	Convolvulaceae
Ixora spp.	Ixora	G	K	T		1		O	Rubiaceae
Jacaranda mimosifolia	Jacaranda				E		2		Bignoniaceae
Jasminum sp.	Jasmine			T					Oleaceae
Jasminum sp.	Lady's of the night			T					Oleaceae
Jasminum spp.					E		3		Oleaceae
Jasminum sambac	Arabian jasmine				E				Oleaceae
Kalanchoe sp.	Kalanchoe, wonder of the world			T					Crassulaceae
Kigelia sp.					E				Bignoniaceae
Lactuca sativa	Lettuce	G				1		V	Asteraceae
Lagerstroemia speciosa	Queen of Flowers	G	K			1		Fo/O	Lythraceae
Lantana					E				Verbenaceae
Lantana camara	Lantana			T					Verbenaceae
Laportea aestuans	Stinging nettle			T					Urticaceae
Lawsonia					E				Lythraceae
Leonotis nepetifolia	Honeysuckle, Shandileer	G		T		1		W	Lamiaceae
Leucaena glauca = Leucaena leucocephala	Leucaena								
Leucaena leucocephala	Leucaena	G	K			1		AF	Fabaceae
Lycopersicon esculentum	Tomato	G			E	1	3	V	Solanaceae
Malpighia glabra	Barbados/W.I.-cherry	G		T		1		Fr	Malpighiaceae
Malpighia punicifolia = M. glabra									Malpighiaceae
Malvaviscus arboreus					E		2		Malvaceae
Mangifera indica	Mango	G	K	T	E	1	2	Fr	Anacardiaceae
Manihot esculenta	Cassava	G		T	E	0		RC	Euphorbiaceae
Manilkara zapota	Sapodilla	G				1		Fr	Sapotaceae
Medicago sativa					E				Fabaceae
Melia azederach	Chinaberry				E		3		Meliaceae
Melicocca bijuga = Melicoccus bijugatus									Sapindaceae
Meliococca arvense	Chennette			T					
Melicoccus bijugatus	Genip, Chenette	G		T		1		Fr	Sapindaceae
Miconia cornifolia	Mal Estomac	G				1		W	Melastomataceae
Mikania cordata	Mile-a-minute				E				Asteraceae
Mimosa pudica	Sensitive plant			T					Fabaceae

E9. Plants Infested by *Maconellicoccus hirsutus—Continued**

Botanical Name	Common Names	Carib.			E	Pref.		Use	Family
		G	K	T		C	E		
Morus sp.					E				Moraceae
Morus alba	White mulberry				E		1		Moraceae
Morus nigra	Black mulberry				E		2		Moraceae
Murraya exotica	Sweet lime			T					Rutaceae
Murraya koenigii	Curry leaf or karapuela			T					Rutaceae
Murraya paniculata	Sweetlime, myrtle	G		T		1		O	Rutaceae
Musa spp.	Banana, Plantain	G		T		1		Fr	Musaceae
Mussaenda spp.	Mussaenda	G	K	T		1		O	Rubiaceae
Myrtus communis	Myrtle				E		3		Myrtaceae
Nephrolepis biserrata furcans	Fish tail fern			T					Polypodiaceae
Nephrolepis exaltata	Boston fern			T					Polypodiaceae
Nerium odorum					E				Apocynaceae
*Nerium oleander**	Oleander	G	K	T	E	2	3	O	Apocynaceae
Opuntia					E				Cactaceae
Pachystachys lutea	Shrimp Plant			T					Acanthaceae
Paritium					E				Malvaceae
Parkinsonia aculeata					E		1		Fabaceae
Parthenium hysterophorus	Whitehead, white top	G		T		1		W	Asteraceae
Passiflora edulis var. *edulis*	Passionfruit	G	K	T		1		Fr	Passifloraceae
Passiflora granadilla	Barbadeen			T					Passifloraceae
Passiflora quadrangularis					E		3		Passifloraceae
Pavonia					E				Malvaceae
Peperomia pellucida	Shining bush			T					Piperaceae
Pereskia bleo	African rose			T					Cactaceae
Persea americana	Avocado	G	K	T		1		Fr	Lauraceae
Petiveria alliacea	Maoui poui	G				1		W	
Petrea arborea	Petrea	G				1		O	Verbenaceae
Phaseolus mungo = *Vigna mungo*									Fabaceae
Phaseolus vulgaris	beans, String	G			E	1	2	V	Fabaceae
Philodendron sp.	Philodendron			T					Araceae
Phoenix dactylifera	Date				E		2		Arecaceae
Phoenix sylvestris					E				Arecaceae
Phyllanthus acidus	Damson	G				1		Fr	Euphorbiaceae
Phyllanthus amarus	Seed under leaf	G		T		1		W	Euphorbiaceae
Phyllanthus niruri					E				Euphorbiaceae
Piper tuberculatum	Candle bush or cigarette weed			T					Piperaceae
Plumbago auriculata	Plumbago			T	E		2		Plumbaginaceae

E9. Plants Infested by *Maconellicoccus hirsutus—Continued**

Botanical Name	Common Names	Carib.			E	Pref.		Use	Family
		G	K	T		C	E		
Plumbago capensis = *P. auriculata*									Plumbaginaceae
Poinciana regia = *Delonix regia*	Flametree								Fabaceae
Portulaca oleraceae	Pussley or pursley			T					Portulacaceae
Portulaca pilosa	Jump and kiss			T					Portulacaceae
Prunus armeniaca	Apricot				E		3		Rosaceae
Prunus domestica	Plum				E		3		Rosaceae
Prunus persica	Peach				E		3		Rosaceae
					E				
Psidium guajava	Guava	G	K	T	E	1	1	Fr	Myrtaceae
Punica granatum	Pomegranate			T	E		3		Punicaceae
Pyrus communis	Pear				E		3		Rosaceae
Pyrus cydonia = *Cydonia oblonga*									Rosaceae
Quisqualis					E				Combretaceae
Rhoeo sp.	Boundary plant			T					Commelinaceae
Ricinus communis	Castor-bean				E		3		Euphorbiaceae
Rivina humilis	Cats blood	G				1		W	Phytolaccaceae
Robinia pseudocacia	Black locust				E		1		Fabaceae
Rosa spp.	Rose	G	K	T	E	0	3	O	Rosaceae
Russellia equisetifola	Antigua heath	G				1		O	
Saccharum officinarum	Sugarcane	G		T	E				Poaceae
Salix					E				Salicaceae
Samanea saman = *Albizia saman*									Fabaceae
Schefflera sp.	Schefflera			T					Araliaceae
Schefflera actinophylla	Octopus tree		K	T					Araliaceae
Schefflera elegantissima	False aralia			T					Araliaceae
Schinus molle					E		3		Anacardiaceae
Schinus terebinthifolius					E		3		Anacardiaceae
Sciadophyllum pulchrum					E		3		
Scindapsus aureus	Devil's ivy			T					Araceae
Scoparia dulcis	Sweet broom			T					Scrophulariaceae
Senna italica					E		2		Fabaceae
Senna obtusifolia	Wild senna	G				1		W	Fabaceae
Senna siamea	Cassia			T	E				Fabaceae
Senna sulfurea					E		2		Fabaceae
Sesbania aegyptiaca = *Sesbania sesban* var. *sesban*									Fabaceae
Sesbania sesban var. *sesban*					E		3		Fabaceae

E9. Plants Infested by *Maconellicoccus hirsutus—Continued**

Botanical Name	Common Names	Carib.			E	Pref.		Use	Family
		G	K	T		C	E		
Sida acuta	Broomweed or wire weed	G		T				W	Malvaceae
Solanum aethiopicum					E				Solanaceae
Solanum bicolor				T				O	Solanaceae
Solanum melongena	Eggplant, baigan or melongene			T	E		2		Solanaceae
Spondias chili	Plum			T					Anacardiaceae
Spondias cytherea	Pommecythere, golden-apple		K	T	E				Anacardiaceae
Spondias dulcis = S. cytherea									Anacardiaceae
Spondias mombin	Hogplum		K		E			Fo	Anacardiaceae
Spondias purpurea	Red/Jamaica Plum	G				1		Fr	Anacardiaceae
Spondias purpurea var. *lutea*	Yellow/Chili Plum	G		T		1		Fr	Anacardiaceae
Stachytarpheta jamaicensis	Vervine			T					Verbenaceae
Symedrella nodiflora				T				W	Asteraceae
Syngonium podophyllum				T					Araceae
Syzygium cumini	Jaman	G			E	1		Fr	Myrtaceae
Syzygium malaccense	French cashew, pomerac	G		T	E	1	2	Fr	Myrtaceae
Tabebuia sp.	Poui			T					Bignoniaceae
Tabebuia heterophylla	White-cedar	G				1		Fo	Bignoniaceae
Tabernaemontana divaricata	Chamelie			T					Apocynaceae
Tamarindus indica	Tamarind			T					Fabaceae
Tecoma capensis					E		2, 1b		Bignoniaceae
Tecoma grandiflora					E				Bignoniaceae
Tecoma stans					E		2		Bignoniaceae
Tectona grandis	Teak	G			E	1		Fo	Lamiaceae
Templetonia					E				Fabaceae
Terminalia spp.					E		2		Combretaceae
Terminalia catappa					E				Combretaceae
Terminalia mantaly					E				Combretaceae
Theobroma cacao	Cocoa	G			E	1		S	Sterculiaceae
Thunbergia erecta	Thunbergia			T					Acanthaceae
Tithonia urticifolia					E				Asteraceae
Vigna unguiculata	Bodi	G	K	T		1		V	Fabaceae
Vinca minor	Common periwinkle			T					Apocynaceae
Vitis vinifera	Grape	G	K	T	E	1	2	Fr	Vitaceae
Xanthosoma sp.	Tannia	G		T					Araceae
Zea mays					E				Poaceae
Ziziphus *sp.*					E				Rhamnaceae

E9. Plants Infested by *Maconellicoccus hirsutus—Continued**

Botanical Name	Common Names	Carib. G	Carib. K	Carib. T	E	Pref. C	Pref. E	Use	Family
Ziziphus jujuba					E		1		Rhamnaceae
Ziziphus mauritiana	Dunks	G		T		1		Fr	Rhamnaceae
Ziziphus mucronata					E				Rhamnaceae
Ziziphus spina-christi					E		1		Rhamnaceae
Ziziphus vulgaris = *Ziziphus jujuba*									Rhamnaceae
-	Oregano thyme		K						
-	Pon-pom		K						
-	Wild coffee	G				2		W	
	Palms			T					Arecaceae
-	numerous grassy weeds		K	T					Poaceae
-	Leguminous weeds		K						Fabaceae

* Symptoms only (Programme Management Committee 1995)
Location codes: G Grenada, K St. Kitts, T Trinidad, E Eastern Hemisphere.

Host preference codes:

C Caribbean — Grenada (Persad 1995)
1. Favors host and reproduces on it
2. Feeds but neither colonizes nor reproduces
3. Colonizes host only at flowering and fruit set
0. Neither feeds nor colonizes these plants

E Eastern Hemisphere — Egypt (Hall 1921)
1. Thrives and breeds rapidly
   1b Primary (Hall 1926)
2. Lives and breeds but rarely badly attacked unless near heavy infestation
3. Rarely found, never serious damage

Use in Caribbean:
AF Animal Fodder
FC Food Crop
Fo Forest
Fr Fruit
O Ornamental
RC Root Crop
S Spice
V Vegetable
W Weed

Major sources: Francis-Ellis 1995 for Grenada. Jones 1996 for Trinidad. Hall 1921 and Mani 1989 for the Eastern Hemisphere. Persad 1995 for Grenada. Programme Management Committee 1995 for the Caribbean.

Checked names with National Genetic Resources Program; GRIN, Germplasm Resources Information Network; National Plant Germplasm System [Database]. Beltsville, MD: U.S. Department of Agriculture, Agricultural Research Service.

E10. Wind Dispersal of Coccoidea First-instar Nymphs

Insect	Windborne up to
Pine tortoise scale (a soft scale)	5 km (3.1 miles)
Pine needle scale (an armored scale)	3 km (1.9 miles)
Red pine scale (a margarodid scale)	1.6 km (1.0 miles)
California red scale (an armored scale)	0.3 km (0.19 miles)
Elongate hemlock scale (an armored scale)	0.1 km (0.06 miles)
Icerya seychellarum (a margarodid scale)	a few km

Source: Pedgley 1982

E11. Distance between Selected Caribbean Islands

Islands	Miles
Trinidad and Tobago	20+
Trinidad and Venezuela	7 or 8
Grenada and St. Vincent (Main Islands)	60+
Grenadines (St. Vincent) and Carriacou (Grenada)	0.2
St. Kitts and St. Croix	110
St. Kitts and Nevis	2.5
Nevis and Montserrat	30

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